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PROGRAM DOCUMENTATION FOR THE HELMET-MOUNTED-DISPLAY PROCESSOR FLIGHT SOFTWARE

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AMRL-TR-78-38

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

CHARLES BATES, JR.
Chief
Human Engineering Division
Aerospace Medical Research Laboratory

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The flight software executes in the Helmet-Mounted-Display Processor (HMDP) to provide vector-graphic displays that may be viewed on a helmet-mounted display (HMD), or a heads-up display (HUD). There are several different display formats, each of which is selectable via pushbutton switches mounted in a cockpit mockup. In addition, to these display selection inputs, the program is responsive to data value inputs which can be expressed using these same pushbuttons under various modes. → next page

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20. Abstract (continued)

Dynamic data received from actual aircraft electronics units are accommodated by an analog input capability and a synchro input capability. These dynamic inputs define the aircraft state and the helmet pointing angles to the flight software program.

The various display generation routines that comprise the flight software program use these dynamic and static inputs to derive meaningful flight displays in several specific orientations, all of which are dynamically responsive to aircraft translation and rotation, as well as head pointing angle. In addition, the vector-graphics displays when viewed on the HMD may be mixed with a T.V. image.

The HMD vector-graphics is employed as a virtual HUD display in one mode. This is accomplished by shifting the display sufficiently to compensate for movement of the helmet with respect to the aircraft center line. The vector-graphics can be mixed with a T.V. image from a camera whose gimbal angles are also driven by the helmet pointing angle. The vector-graphics of the virtual HUD therefore appear to be locked onto one point in the T.V. scene.

The helmet pointing angle can also be used to designate points on the ground and record their geographic coordinates. The flight software will display these designated points as virtual earth points so that they may be used as visual references for the balance of the flight, even though the actual terrain becomes obscured by weather or darkness. Fly-to-points, that provide the same navigation capability, are entered into the HMDP using the numeric pushbuttons to specify a geographic coordinate. A Continuously Computed Impact Point (CCIP) is also available.

A Flight Situation Display is available for both HMD and the HUD. Additional displays provide a capability for HMDP system test, initialization of the flight software and a menu for selecting display formats.

PREFACE

This program was developed for the Human Engineering Division, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio 45433. The work was performed by the International Business Machines Corporation, Owego, New York 13827, under Contract Number F 33615-75-C-5152. Mr. Dean F. Kocian of the Visual Display Systems Branch was the contract monitor for the Aerospace Medical Research Laboratory. The work was performed in support of Project 7184, "Man-Machine Integration Technology," Task 718414, " Operator Workload Assessment."

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SECTION I

Introduction

This document, along with the ~~program~~ listings and card decks discussed herein, represents the total documentation package for the Helmet-Mounted-Display processor Flight Software. This flight software was developed to provide display generation and control for the HMDP.

The flight software executes in the Helmet-Mounted-Display Processor (HMDP) to provide vector-graphic displays that may be viewed on a helmet-mounted display (HMD), or a heads-up display (HUD). There are several different display formats, each of which is selectable via pushbutton switches mounted in the F-16 cockpit. In addition to these display selection inputs, the program is responsive to data value inputs which can be expressed using these same pushbuttons under various modes. A second pushbutton control panel mounted in the instrumentation rack may also be employed during those occasions when the cockpit is not occupied.

Dynamic data received from actual aircraft electronics units are accommodated by an analog input capability and a synchro input capability. These dynamic inputs define the aircraft state and the helmet pointing angles to the flight software program.

The various display generation routines that comprise the flight software program use these dynamic and static inputs to derive meaningful flight displays in several specific orientations, all of which are dynamically responsive to aircraft translation and rotation, as well as head pointing angle. Listed below are some of the more prominent dynamic display formats.

The Flight Situation Display represents attitude information via a pitch ladder and a vector-graphic horizon. In addition, it contains replicas of tape instruments for speed, altitude, and heading. This information is viewable on the HMD or the HUD.

The Horizon Display contains the same instrument information as the FSD but in a compressed form. In addition, the instruments and tapes, when viewed on the helmet CRT, are made to appear stabilized to the aircraft center line so that they provide a HUD display held in a fixed position even though the helmet pointing angle is varied. This feature therefore provides the capability for HUD displays, without

employing the actual physical HUD. The stabilization is accomplished by shifting and reorienting the instruments and tapes as a function of the received helmet azimuth and elevation angles. The vector-graphic horizon is positioned via another set of logic, so that it appears locked to the actual horizon that would be visible if the aircraft were airborne. The horizon display also contains terrain information in the form of a perspective view of points and lines on a simulated earth.

Fly-to-points can be defined in latitude-longitude coordinates using the control panel push-buttons. These are viewable when the helmet field-of-view encompasses the geographic location of the points.

Likewise, designated targets are displayed when the helmet field-of-view encompasses their geographic location. The original designation of the target is accomplished by computing the coordinates of the earth point that is being looked at when the pilot depresses the target key.

The head pointing-angle is also employed as a device for display selection and control. A display stabilized to the aircraft center line is used for item selection. This display contains 6 labelled squares that define the available selections. The instantaneous helmet pointing angle is used to deflect a cursor relative to these selection squares. The pilot makes his selection by turning his head until the cursor position matches the square position and then depresses the select key.

Intermediate displays that are used in support of the dynamic displays include the Fly-to-Point Tableau, the Target Tableau and the Display Option Menu. An Initialization Display allows for calibration of the helmet display field-of-view and also permits initial parameters such as initial position to be specified.

A System Test Display is available for the purpose of verifying the correct operation of the HMDP while airborne.

Detailed instructions for using these displays and controls are available in Appendix I - Operating Instructions.

As presently employed, the HMDP is ground-based, being located in the HESS facility computer room. Therefore, the HMDP must be supplied with inputs that simulate those

that the aircraft would provide in an actual airborne situation. These inputs include:

- o Heading
- o Position
- o Altitude
- o Pitch Angle
- o Roll Angle
- o Speed
- o Bomb Impact Point Coordinates

Dynamic values are provided to the HMDP by the System 370 program Terrain and Flight Dynamics (TFD). The TFD program contains a flight simulation that is responsive to pilot stick and throttle control movements so that at any given point in time aircraft state is completely defined. In addition, TFD simulates the activities of a bombing-navigation computer to derive the dynamic coordinates of a Continuously Computed Impact Point (CCIP). The transmission link from TFD in the S/370 to the flight software in the HMDP is implemented by employing the S/370 analog output to produce voltage values representing these aircraft and bomb state variables. The analog input section of the HMDP is used to receive these voltage values.

During test and calibrate activities, the HMDP analog inputs can be connected to potentiometers, allowing manual adjustment of static values for these same variables.

The helmet pointing angle inputs to the HMDP are received from the Helmet-Mounted Sight (HMS) electronics unit just as they would be received in an actual airborne situation. The HMS equipment, manufactured by Honeywell Corp., senses the helmet pointing angle using infra-red scanning beams directed toward sensors mounted on the helmet. A computer resolves these sensor dynamic values into values representing the current azimuth and elevation angles with respect to the aircraft center line. Various representations of these values are available. For the HMDP, a linear voltage representation was chosen so that the HMDP analog inputs could be employed. The azimuth and elevation values can also be provided to the HMDP by using manually adjustable potentiometers.

Detailed coverage of these HMDP inputs is presented in Section IV - Input-Output Formats.

SECTION II

Hardware Requirements

The Helmet-Mounted-Display Processor Flight Software is executable in the Helmet-Mounted-Display Processor (HMDP). This is an airborne processor designed and built specifically by the IBM Federal Systems Division specifically for AMRL. This processor is basically an IBM SP-1 computer that was augmented to meet special AMRL requirements. The augmentation for display generation consisted of attaching the Display Electronics Unit (DEU) to the SP-1. The DEU was originally developed by IBM for the Space Shuttle. Similarly, the requirements for other inputs and outputs were met by attaching units that originated from other government programs. A complete description of the HMDP is available in "Theory of Operation for the Display Processor System," IBM NO. 76-A60-001, which was delivered as part of the HMDP development contract, F33615-75-C-0095. Description of the basic SP-1 computer is available in "SP-1 Computer Technical Description," IBM NO. 75-70M-094, and "SP-1 Principles of Operation," IBM NO. 72-A31-004. These also were a part of the HMDP hardware delivery under contract F33615-75-C-0095. A capsule summary of these documents is given in Table # 1 for purposes of orientation.

Memory	-	16K Words
Word Length	-	16 Bits
DC Analog Inputs	-	14 Inputs
AC Analog Inputs	-	6 Pairs
Synchro Inputs	-	4 Three-wire Inputs
Discrete Inputs	-	8 Bits TTL
Discrete Outputs	-	8 Bits TTL
Display Output	-	Direct Draw, High Speed for HMD
Display Output	-	Direct Draw, Low Speed for HUD
Sensor Video Input	-	RS-170 Composite Video
Panel Adapter Inputs	-	DMA Direct In and Out
Pushbutton Controls Panels	-	Command and Data Pushbuttons

Table 1. HMDP Summary

In addition to the HMDP itself, the flight software requires input and output devices to support the operation of the program. These include the references for the analog and synchro inputs, the composite video, and the HMD and HUD display units. Inputs from the Helmet-Mounted-Sight equipment and the S/370 can be replaced, for test purposes, by DC voltage sources if these voltages are kept within ranges in accordance with requirements stated in Section IV, Input-Output Formats.

Loading the flight software into the HMDP requires another set of hardware, known as the Microprogrammed Test Set (MTS). The MTS is a set of Aerospace Ground Equipment (AGE) that connects to the HMDP AGE receptacles and provides facilities for magnetic tape input/output, displays of internal computer registers, and manual control of register contents. These facilities are useful for diagnosing hardware failures as well as for debugging programs. All of these transfers of data into, and out of, the HMDP are controlled by a specific microprogram that is read into the MTS via magnetic tapes prior to using the MTS as an AGE device. A complete description of the MTS is available in "MTS User's Manual, SP-1 Version," IBM NO. 75-290-012.

Development of programs for the HMDP is accomplished by employing a cross-assembler that executes on the IBM System 360 or System 370. The cross-assembler and associated support facilities are described in detail in "SP-1 Support Software System Software Systems Manual," IBM NO. 61-22264. The hardware presently being used by the support software at AMRL is listed in Table # 2. In addition to the hardware and the MVT version of the S/370 operating system, the support software requires the H level of the S/370 assembler.

Device or Function	Type
Central Processing Unit (CPU)	IBM System/370, Model 155
Memory	CDC 33155 Memory System
Disk Storage	ITEL 7830 Storage Control Unit with three 7330 Storage Drives
Magnetic Tape Control	STC 3800-III Control Unit
Card Reader	IBM 2501 Card Reader
Printer	IBM 1403 Printer
CPU Console	IBM 3215 Console-Printer Keyboard

Table 2. - Hardware Employed by the Support Software

SECTION III

Program Description

The HMDP program primarily consists of two major programs, the display program and the main program. The display program consists of display feature control words and data that, when interpreted and executed by the display processor, generate all HMD and HUD displays. The display buffer, containing display commands, is continuously executed at the display processor refresh rate. The main program is the SP-1 executable program whose primary function is to dynamically update and/or alter the display program based on updated analog and discrete inputs and various operator commands.

The main program consists of three main structural sections. They are essentially the initialization section, dispatcher, and panel processor. The initialization section is invoked at power-up time or during a reset of the processor. It initializes necessary flags and parameters, presets various hardware devices, and starts the A/D converter subsystem to cyclically recirculate new analog flight parameter values. After the initialization phase, control is turned over to the dispatcher.

The dispatcher (DISPATCH) is responsible for properly executing various tasks, thus controlling cyclic execution of these tasks based on the SP-1 timing clock source. The timer interrupt routine (TIMER) updates the timing increment for each scheduled task so that the dispatcher can direct control to them at the appropriate incremental time. The panel processor (PANELS) is responsible for the scheduling of tasks to the dispatcher.

The main processor tasks controlled by the dispatcher are the following. The navigation process (NAVIGATE) maintains the aircraft's present position (latitude-longitude), altitude, and current mission time for use by other parts of the program's calculations. It is scheduled when the operator has selected the horizon display and has put the aircraft in the GO mode. This process is thereafter executed at four times per second.

The analog input processor (AIPROC) updates various aircraft parameter values based on new digitized analog values representing these values. It updates helmet azimuth and elevation, aircraft roll, aircraft pitch, aircraft airspeed, and angle of attack. The values are used in other parts of the program. It is scheduled at power-up time and is executed at 20 times per second to provide a fine resolution for the values.

Subroutine Name	Function(s)	Called by:
POWER	Initialization procedures; resets hardware; resets software.	Entered when power or reset interrupt (external interrupts).
DISPATCH	Transfers control to scheduled and pending cyclic/noncyclic processes.	POWER
XSCEDULE	Schedules processes to be ran by dispatcher.	POWER, XTCUE TQENTER, INSPCHA, INADDR, TINDXFP.
INTPROC	Interrupt processor determines occuring interrupt and calls appropriate routine.	Entered when internal interrupt occurs such as TIMER, data ready, RESET.
TIMER	Handles clock interrupts; resets clock; maintains system timer word; updates scheduled cyclic process counts.	INTPROC
DTARDY	Handles data ready interrupts; reads A/D values.	INTPROC
NAVIGATE	Computes TOD, local earth's radius, current A/C latitude and longitude, and A/C altitude.	DISPATCH
CMODESEL	Determines which mode box should be flashed as function of current head display coordinates.	DISPATCH
MODESEL	Handles MODE button depressions and sets current mode to that selected.	PANELS
PANELS	Handles discrete inputs from pilot/operator; calls appropriate key depression routines; in conjunction with key depression routines, it handles the presenting and processing of visual cues and the scheduling of cyclic tasks to the dispatcher.	DISPATCH
DC01	Updates initialization tableau parameter values such as time and current latitude and longitude.	DISPATCH
CHORIZON	Updates horizon display presentation as function of A/C and head parameter values.	DISPATCH
COMPHDG	Updates A/C heading along with the A and H matrices.	DISPATCH
TEST	Handles TEST button depressions; saves previous state of machine and puts up the test display.	PANELS
TODIGITS	Handles DIGIT button depressions; schedules for execution (when ENTER depressed) routines to do further processing of digit string depending on the cue that is being responded to.	PANELS

Table 3. - Subroutine Functions

Subroutine Name	Function(s)	Called by:
TRGFPRO	Processes response from DELETE X cue when ENTER button depressed. It modifies the TARGET tableau display.	TOENTER
TARGETB	Handles TARGET button depressions; computes current LOS (line-of-sight) and updates TARGET tableau display and TARGET tables.	PANELS
TINDXFP	Handles display selection responses for table tableau. Schedules the appropriate cyclic process that maintains the selected display and puts up the appropriate cue for that selection. Also schedules other routines for further processing when ENTER is depressed.	TOENTER
TABLEIN	Handles TABLE INDEX button depression; displays the display option menu or blanks it if it was previously displayed. Properly sets backlighting.	PANELS
ITFPO	Puts up the proper cues depending on the selection from the initialization tableau. Also stores the numerically inserted cue values as initialized parameter values.	TQENTER
FTPFPROC	Takes numerically inserted latitude and longitude values for fly-to-point to update fly-to-point tableau.	TQENTER
TTFURPRO	Deletes selected target from tables and displays.	TQENTER
TQENTER	Handles ENTER button depressions. Validates operator responses to active cues and converts to appropriate units. Executes appropriate routines that do further processing on the entry.	PANELS
XTCNCL	Handles CLEAR key depressions. Reinitializes accumulated entries for active display and re-displays that cue.	PANELS
XTBKSP	Handles BACK SPACE key depressions. Eliminates the latest response entry to the current active cue.	PANELS
HMDSEL	Handles A button depressions. Blanks HMD display and sets up for HUD display.	PANELS
HUDSEL	Handles B button depressions. Blanks HUD display and sets up for HMD display.	PANELS
DELCLUT	Handles C button depressions. Blanks FSD symbology for HMD and HUD horizon display.	PANELS
CFLIGHT	Updates flight situation display presentation as function of A/C parameter values.	DISPATCH
AIPROC	Updates A/C parameter values based on new digitized analog values.	DISPATCH

Table 3. - Subroutine Functions (Continued)

The heading computation process (COMPHDG) updates aircraft heading, computes the sine and cosine of aircraft heading, pitch, and roll; the sine and cosine of helmet azimuth, elevation, and tilt; and updates the A and H matrices. A description of the A and H matrix operations is presented at the end of this section. This process is scheduled at power-up time and is executed at 10 times per second.

The remaining processes handled by the dispatcher are mostly for display update. They use the updated parameter values provided by the previously mentioned processes in order to update the display program for display presentation.

The mode selection process (MODESEL) uses current head position in order to indicate to the pilot which mode is in view for selection. Depending on head position relative to display coordinates, it will modify the display program to blink the appropriate box representing the mode of potential selection. This process is scheduled when the operator has selected the mode display. It is executed at 20 times per second until a new display is selected.

The flight situation display update process (CFLIGHT) uses updated parameter values from previously mentioned cyclic processes in order to update the presentation of the flight situation display. This process is scheduled when the flight situation display is selected. It executes at 10 times per second until a new display is selected.

The horizon display update process (CHORIZON) uses updated parameter values from previously mentioned cyclic processes in order to update the presentation of the horizon display. This display, not detailed here, is updated by using new head azimuth and elevation values, altitude, airspeed, pitch, CCIP azimuth and elevation, roll, heading values, present A/C position, and other earth and optical descriptive values to perform calculations that eventually get described into display command information. This process is scheduled when the horizon display is selected. It is executed at 20 times per second until a new display is selected.

The third section of the HMDP program is the panel processor (PANELS). It is controlled by the dispatcher and executes at 4 times per second. The panel processor handles discrete inputs. It calls appropriate routines to handle all key depressions. These consist of digit depressions, CLR, BKSP, ENTER, SYSTEM TEST, TABLE INDEX, TARGET, MODE, A, B, and C. Each key depression triggers a call to an appropriate routine to carry out the operations for the proper function of that key as detailed elsewhere in this document. The routines (see flowcharts), together with the panel processor, handle the presentation and processing of visual operator cues and the scheduling of previously mentioned cyclic tasks for synchronous execution by the timer controlled dispatcher.

The A and H matrix operations are crucial to resolving relative angles. The following description is keyed to the program listing so that these operations can be followed. Beginning directly below label COMPHDG7, the sine and cosine of aircraft pitch, roll, and heading and helmet pitch, roll, and heading are computed and stored. These values are needed to compute the aircraft (A) matrix and the helmet (H) matrix.

After these values are determined, two branches are made to label XCME. This is where the actual computation of matrices A and H is made. On the first branch to XCME, the aircraft angles are used and the A matrix is computed. The A matrix allows points in earth coordinates to be expressed in terms of aircraft coordinates. On the second branch to XCME the helmet angles are used and the H matrix is computed. The H matrix allows points in aircraft coordinates to be expressed in terms of helmet coordinates.

Both the A and H matrices are basically the same and have the following form:

CH·CP	CH·SP·SR - SH·CR	CH·SP CR + SH·SR
SH·CT	SH·SP·SR + CH·CR	SH·SP CR - CH·SR
-SP	CP·SR	CP CR

CP = COS (PITCH)	CH = COS (HEADING)	CR = COS (ROLL)
SP = SIN (PITCH)	SH = SIN (HEADING)	SR = SIN (ROLL)

Computation of the AH matrix is done at label SPC. The AH matrix is the product of the A and H matrices and allows points in earth coordinates to be expressed in terms of helmet coordinates.

SECTION IV

Input-Output Formats

The HMDP flight software uses analog inputs while cycling to receive aircraft state and other parameters from aircraft electronics units. While ground based in the S/370 room of the HESS facility, these inputs are driven by either the analog output section of the 1827 DCU or by a potentiometer panel. In either case, or in an airborne environment, the flight software expects certain characteristics to exist in these analog voltages.

Table 4 and Table 5 show, in abbreviated form, what is expected by the flight software. It should be noted that the 2 AC analog inputs being used are employed with a DC reference so that they are really being used for additional DC analog inputs.

The employment of some of these analog inputs is straight forward linear representation of physical values by scaled voltages. However, the usage of pairs of analog inputs to define rotating vectors requires special explanation. This rotating vector approach was chosen to accommodate the extreme precision requirements of some of the parameters. For instance, representing altitude on a linear voltage scale would not have been possible except to a precision that was attainable with a 20 volt (±10) excursion and a noise margin of 20 millivolts. This would have only allowed a precision of 1 part in 1,000. Therefore, in attempting to cover a range of 40,000 feet, a 40 foot change would have been equivalent to the RMS noise value. Therefore, the received value would indicate an RMS movement of 40 feet on the altimeter when the noise was 20 millivolts or would have to have been subjected to thresholding at increments of something larger than steps of 40 feet. The same kind of considerations apply to latitude and longitude. For heading, the precision requirement was dictated by the requirement to work in consonance with the received angles from the HMS and therefore resolve much better than 0.1 degree so as to not add false movement to sighted ground points. One part in 1,000 would have given only 0.360 degrees resolution, and then accompanied by the RMS of the ambient noise.

Using a rotating vector representation allows a full circle to represent any modular value desired, such as 2,000 feet for altitude. When a value such as 2,100 feet is to be represented, only the least significant part (100 feet) is

TABLE 4 - HMDP DC INPUTS

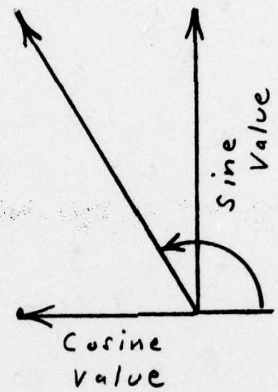
NO.	NAME	VOLTAGE SCALING
01	Helmet Azimuth	0.1 volt per degree (nominal). Plus volts for Right Azimuth.
02	Helmet Elevation	0.1 volt per degree (nominal). Plus volts for up Elevation.
03	Heading - Sine	Sine component times 9.8 volts. One revolution for 20 degrees Hdg. change
04	Heading - Cosine	Cosine component times 9.8 volts. One revolution for 20 degrees Hdg. change
05	Roll	Neg. 9.8 volts for 180 degree left roll, pos. 9.8 volts for 180 degree right roll. Linear
06	Pitch	Neg. 9.8 volts for 90 degrees down pitch, pos. 9.8 volts for 90 degrees up. Linear
07	Speed	Neg. 9.8 volts for zero speed, pos. 9.8 volts for 1500 knots. Linear
08	Angle-of-Attack	Same as Pitch.
09	Latitude - Sine	Sine component times 4.8 volts, plus 5 volts. One revolution for 20 second Latitude change.
10	Latitude - Cosine	Cosine component times 4.8 volts, plus 5 volts. One revolution for 20 second Latitude change.
11	Longitude - Sine	Same as Latitude sine.
12	Longitude - Cosine	Same as Latitude cosine.
13	Altitude - Sine	Sine component times 4.8 volts, plus 5 volts. One revolution for 2,000 ft. Altitude change.
14	Altitude - Cosine	Cosine component times 4.8 volts, plus 5 volts. One revolution for 2,000 ft. Altitude change.

TABLE 5 - HMDP AC INPUTS

NO.	NAME	VOLTAGE SCALING
01	CCIP Azimuth	0.1 volt per degree. Plus volts for Right Azimuth.
03	CCIP Elevation	0.1 volt per degree. Plus volts for up elevation.

transmitted. The flight software maintains a count of full circle transitions, up or down, to derive the most significant 2,000 foot steps of altitude. While this scheme is not as desirable as a method for continuously explicitly sending the entire altitude, it does provide good precision with the limited input capabilities available in the present HMDP. Addition of a digital bus capability to the HMDP would allow explicit coding of all desired values.

In particular, the rotating vector scheme may be diagrammed as shown below.

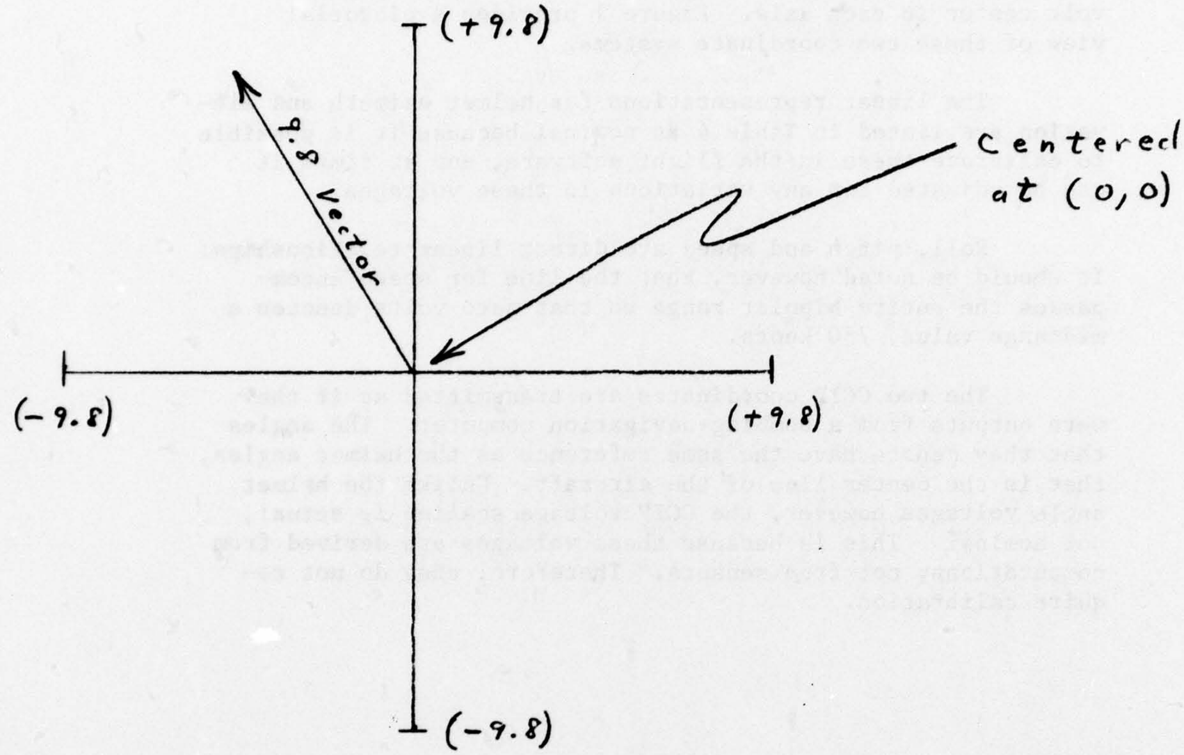


The flight software uses the received voltages for sine and cosine components to derive the angle of the vector within the circle, in this case, 120 degrees. This fraction of a circle, in this case one-third of a circle, is then multiplied by the appropriate scaling for a full circle, see Table 4.

Listed below are the full circle (one revolution) scaling for each of the parameters that use this scheme. The resultant physical meaning derived from the application of one-third of a circle is also shown.

Parameter	One Revolution	One Third Rev.
Heading	20 degrees Heading	6.66 degrees
Latitude	20 seconds Latitude	6.66 seconds
Longitude	20 seconds Longitude	6.66 seconds
Altitude	2,000 feet Altitude	666.66 feet

The sine-cosine values used to derive the vector position in the above example themselves must be derived. The voltages used to denote component values are in two different classes. The heading components are transmitted by the bipolar DACS of the 1827 DCU and therefore can be directly scaled up from trigonometric scaling of unit size to 9.8 volts. The latitude, longitude and altitude parameters are



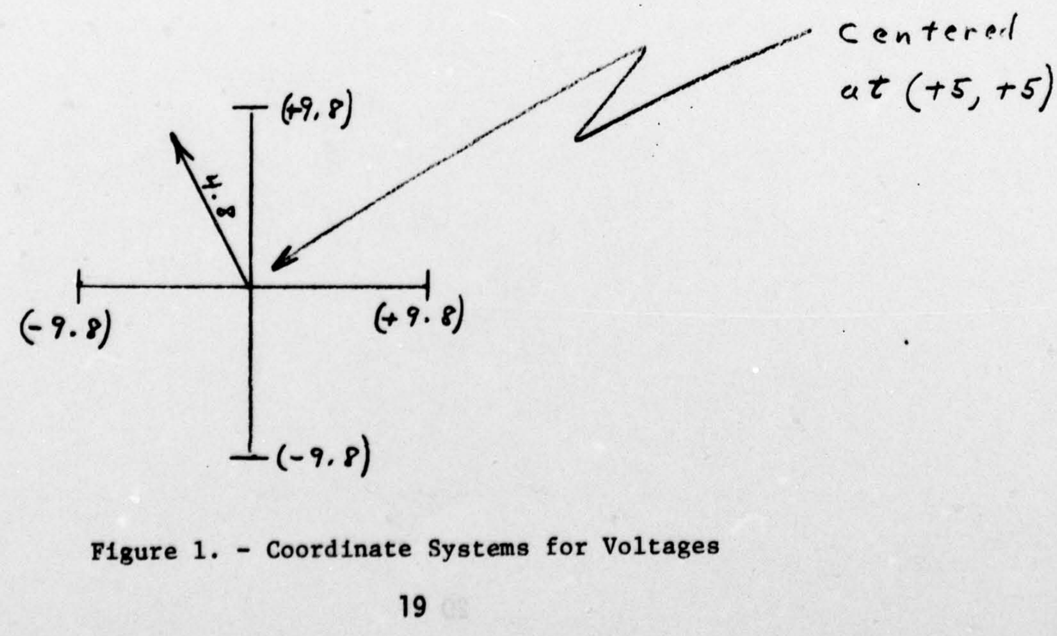


Figure 1. - Coordinate Systems for Voltages

transmitted by unipolar DACS and therefore all component values are transmitted as positive voltages. An offset of plus 5 volts is used to allow positive and negative component excursions. The rotating vector is scaled to 4.8 volts so that the component excursions are +4.8 volts around a 5 volt center in each axis. Figure 1 provides a pictorial view of these two coordinate systems.

The linear representations for helmet azimuth and elevation are listed in Table 4 as nominal because it is possible to calibrate these in the flight software, and at times it can be adjusted for any variations in these voltages.

Roll, pitch and speed are direct linear relationships. It should be noted however, that the line for speed encompasses the entire bipolar range so that zero volts denotes a midrange value, 750 knots.

The two CCIP coordinates are transmitted as if they were outputs from a bombing-navigation computer. The angles that they denote have the same reference as the helmet angles, that is the center line of the aircraft. Unlike the helmet angle voltages however, the CCIP voltage scaling is actual, not nominal. This is because these voltages are derived from computations, not from sensors. Therefore, they do not require calibration.

SECTION V

Displays & Controls

This section is devoted to the Displays and Controls available when executing the flight software in the HMDP. These displays and controls are those that are associated directly with the HMDP and do not include the cockpit stick and throttle that are interfaced to the TFD program.

Display Formats - Eight distinct vector-graphic display formats are available, each of which can be directed to the HMD or the HUD. In addition, the HMD vector-graphics can be mixed with a TV image or the TV image can be viewed exclusive of any vector-graphics. The eight formats are described below with differences between the HMD version and the HUD version if applicable.

DISPLAY OPTION MENU - The Display Option Menu consists of a list of all the display formats (except TEST) that can be selected for display. To select a display option, the operator depresses one of the keyboard pushbuttons 1-6 for the desired format. Both HMD and HUD option menus are identical.

FLY-TO-POINT TABLEAU - The Fly-To-Point Tableau consists of a list of 5 fly-to-points stored into the system by manual insertion. Initially the cue "ENTER X" is presented to allow the operator the capability of selecting the number of the fly-to-point to be inserted or replaced. After this cue is satisfied, a second cue "ENTER XX XX XXX"
XXX XX XXX
is provided for insertion of the fly-to-point coordinates. The last character entered for latitude must be N or S. For longitude, the last character must be E or W. The table entry will be blank if there is no fly-to-point stored for that particular entry. Fly-to-point coordinates on the HUD format are displayed one set at a time as the "ENTER X" cue is satisfied.

TARGET TABLEAU - The Target Tableau consists of a list of 6 targets stored into the system by depression of the TARGET pushbutton. When the TARGET pushbutton is pushed, the geographic sight point coordinates of the helmet line-of-sight are computed and stored into the tableau, if an available slot exists in the table. The cue "DELETE X" is also presented on the Target Tableau. This allows the operator to selectively delete previously stored targets. A table entry will be blank if there is no target stored in that particular entry. Target coordinates on the HUD format are displayed one set at a time as the "DELETE X" cue is satisfied.

INITIALIZATION TABLEAU - The Initialization Tableau consists of a list of 6 system parameters that can be selectively added or modified. Initially the cue "ENTER X" is presented to allow the operator the capability of selecting the desired parameter to be added or modified. After the parameter line has been selected, a second cue is provided for insertion of the parameter. The cues associated with each parameter are as follows:

```
Line #1 - ENTER  XX XX XXX
                XXX XX XXX
     #2 - ENTER TIME XX XX XX
     #3 - ENTER ALTITUDE XXXXXFT
     #4 - ENTER HEADING XXXDEG
     #5 - ENTER AIRSPEED XXXXKTS
     #6 - ENTER F-O-V XX
```

The last character entered for latitude must be N or S. For longitude, the last character must be E or W. The units for time are hours, minutes and seconds. Initialization parameters on the HUD format are displayed one set at a time as the "ENTER X" cue is satisfied.

MODE SELECT DISPLAY - The Mode Select Display consists of 5 boxes with a mode designator legend immediately above each box. The center of the display format represented by crosshairs (+) is aligned to the line-of-sight of the helmet. Helmet movement in azimuth and/or elevation causes the display symbology to be repositioned accordingly. A particular mode can be selected by positioning the helmet such that the desired mode box overlays the crosshairs. The mode designator above the box will flash to acknowledge the selection of the box. Depression of the MODE pushbutton will activate the mode and the flashing is stopped. No other modes may be selected unless the format is redisplayed. Mode selection is a capability demonstration only and does not cause the flight software to perform its tasks. The HUD version of the Mode Select Display is identical to the HMD format.

FLIGHT STIUATION DISPLAY - The Flight Situation Display is basically a tactical situation representation of flight parameters. A movable heading tape with fixed pipper to indicate aircraft heading; (2) A fixed airspeed scale with movable pipper to indicate fine airspeed resolution within a 20 knot range and a numeric readout for coarse resolution to 20 knots; (3) A fixed altitude scale with movable pipper to indicate fine altitude resolution within a 1000 foot range and a numeric readout for coarse resolution to 1000 feet; (4) A movable pitch scale with 5^{o} gradations to indicate aircraft pitch deviation from 0^{o} as denoted by

the aircraft symbol fixed at the center of the display; (5) An artificial horizon line which follows the center as a function of aircraft roll angle. The HUD format of the Flight Situation Display is similar, but consists of fewer scale and pitch ladder tics, abbreviated scale numerics, no scale vectors, and no pitch ladder.

HORIZON DISPLAY - The Horizon Display consists of the following items: (1) dashed oblate dimension lines convergent upon the aircraft current heading and spaced at fixed angles apart; (2) fly-to-point symbols (5 max); (3) target symbols (6 max); (4) a 6 x 6 grid of ground points; (5) an aritificial horizon line; and (6) a modified Flight Situation Display presentation aligned to the aircraft center line. Fly-to-points, targets, and the grid points are continuously checked for field-of-view validity. Targets, fly-to-points, and grid points that exceed 15 miles slant range are not displayed. All horizon display symbology is positioned based on helmet azimuth and elevation inputs so that it appears stabilized on the aircraft center line. The FSD presentation is selectable using the clutter/declutter switch (pushbutton 'C'). The HUD format of the Horizon Display is essentially the same except for the modified FSD symbology. It should be noted, however, that the HUD version is only included to compute the pairs of formats for HUD and HMD. The HUD version is unusable because the display translation based on helmet pointing angle is counter productive on the HUD.

TEST DISPLAY - The Test Display consists of an operational program generated test pattern and a pushbutton/rotary switch readout for displaying the legends on each switch. While the test mode is selected, the operator can exercise all the pushbuttons and rotary switch on either the OPR panel or MON panel, and the corresponding legend for the selected switch will be displayed on the TEST display format.

HMDP Controls and Function Keys

Two control panels contain all of the HMDP switches and function keys. In addition the helmet line-of-sight can be thought of as a control because it is used in some modes to cause direct response from the HMDP.

The two control panels are identical, one being mounted in the F-16 cockpit and the other in the instrumentation rack. Authority is passed between the two panels by a rule of most recent usage at either location. The only difference between the two panels is that the pilot's panel (OPR) contains an HMDP Power/Reset switch while the panel mounted in the rack (MON) has none. Listed below is a summary of the switches and controls

HMDP POWER/RESET SWITCH (OPR PANEL ONLY) - The power/reset switch is used to apply power to the HMDP and light the control panels. The RESET position is used to reset the display processor operational program to the beginning of the program.

HMDP PANEL ROTARY SWITCHES - The rotary switches on the OPR panel and MON panel are used to include or omit the vector-graphics or TV image on the HMD. The GRAPHICS switch setting directs computer generated symbology to be displayed on the HMD. The MIX switch setting causes the computer-generated symbology to be mixed with a TV image on the HMD. Using the TV switch setting causes the HMD to be elevated exclusively to displaying the TV image.

"A" - The "A" pushbutton is used to select the HMD as the active display. Depression of the "A" pushbutton will cause the HMD to be blanked, the "A" pushbutton to be backlit green, and the "B" pushbutton backlighting to be restored to red.

"B" - The "B" pushbutton is used to select the HUD as the active display. Depression of the "B" pushbutton will cause the HUD to be blanked, the "B" pushbutton to be backlit green, and the "A" pushbutton backlighting to be restored to red.

"C" - The "C" pushbutton is used to clutter/declutter the horizon display format with the FSD symbology. Initial depression of the pushbutton will cause the FSD symbology to be removed. A second depression will cause the symbology to be restored.

"D" - The "D" pushbutton is a spare pushbutton.

SYSTEM TEST - The SYSTEM TEST pushbutton is used to select the HMDP System Test Mode. Initial depression of the key will result in the System Test format to be drawn on the HMD and HUD CRT's and all function keys on the OPR and MON panels to be backlit green. A second depression of SYSTEM TEST will cause both displays to become blank and panel backlighting status to be restored to its previous status.

TABLE INDEX - The TABLE INDEX pushbutton is used to select the Display Option Menu format to be drawn on the active CRT. Initial depression of the key will put up the menu and backlight the TABLE INDEX pushbutton green. Selection from the menu is accomplished by depressing one of the numeric pushbuttons. A second depression will cause the display to blank and pushbutton backlight to revert to red.

TARGET - The TARGET pushbutton is used to store the computer sight point coordinates into the Target Table provided that: (1) a slot is available in the table and (2) slant range to sight point does not exceed 15 miles.

MODE - The MODE pushbutton is used in conjunction with the Mode Select format to demonstrate mode selection by line-of-sight. To select a Mode, the operator must place the reticle within the desired mode box. When the mode legend above the box flashes, the operator can depress the MODE pushbutton to indicate that selection is desired. When this is done, the legend stops flashing, the pushbutton is backlit green, and mode status is stored in memory. No other mode can be selected unless the display format is deselected and then reselected.

NUMERICS - The balance of the pushbuttons on the control panel are devoted to inserting numeric values, or suffix alphabetic codes for latitude and longitude. The Clear and Backspace pushbuttons can be used while composing numeric entries into the various formats that are displayed as cues of completed characters and remaining characters required.

ENTER - The ENTER button is used to enter composed numerics into the HMDP. It is also used to initiate cycling of the flight software when the NO GO condition is available as shown on the Horizon Display.

SECTION VI

Program Card Decks

Source program card decks are available at the Systems Research Branch, Human Engineering Division of AMRL. A set of printed listings of the source code is also available, both in card image format and in assembled format.

An assembled listing of the HMDP12 program supplements this document. Contained in this assembled listing is the proper JCL to do an assembly of the partitioned source file. The first 4 pages of the listing describe what each member of the assembled file does in the program.

There are 19 members in the data set named FOWGA29M.HMPP12. SOURCE09 on the SYSTEM disk. Members are named HMDP01 thru HMDP12 and HMDP19. These members make up the complete HMDP program. An additional member named HMDP, also on this file, is the member that controls the assembly. It controls the order in which the members are assembled, thus arranging the final memory structure of this program. A listing of this member is provided after the program listing and shows the current program configuration, i.e. the order in which the members are assembled.

Following this, in the listing supplement, is provided an output from the linkage-editor. Notice that the member HMDP is indicated to be INCLUDED. This controls member linkage order also.

The card deck of the HMDP program provided with this document has the members from disk contiguously grouped as one card file. The same member arrangement for assembly has been maintained so that this deck may be assembled directly as one big program. In this case member structure has no meaning and cards representing member HMDP are not needed.

Also provided is a magtape (#192) which contains, as one big file, all the members from the system disk representing the HMDP program. The output from this copy is provided at the end of the listing supplement. This gives all pertinent information for accessing this tape.

SECTION VII

Program Flowcharts

The program flowcharts are presented in Figure 2. Although the flowcharts were done by hand, the conventions used are the same as those described in "AUTODOC-V an Automatic Documentation and Symbolic Flow Charting Program," 360D-001.1.014, available at the Systems Research Branch, Human Engineering Division of AMRL.

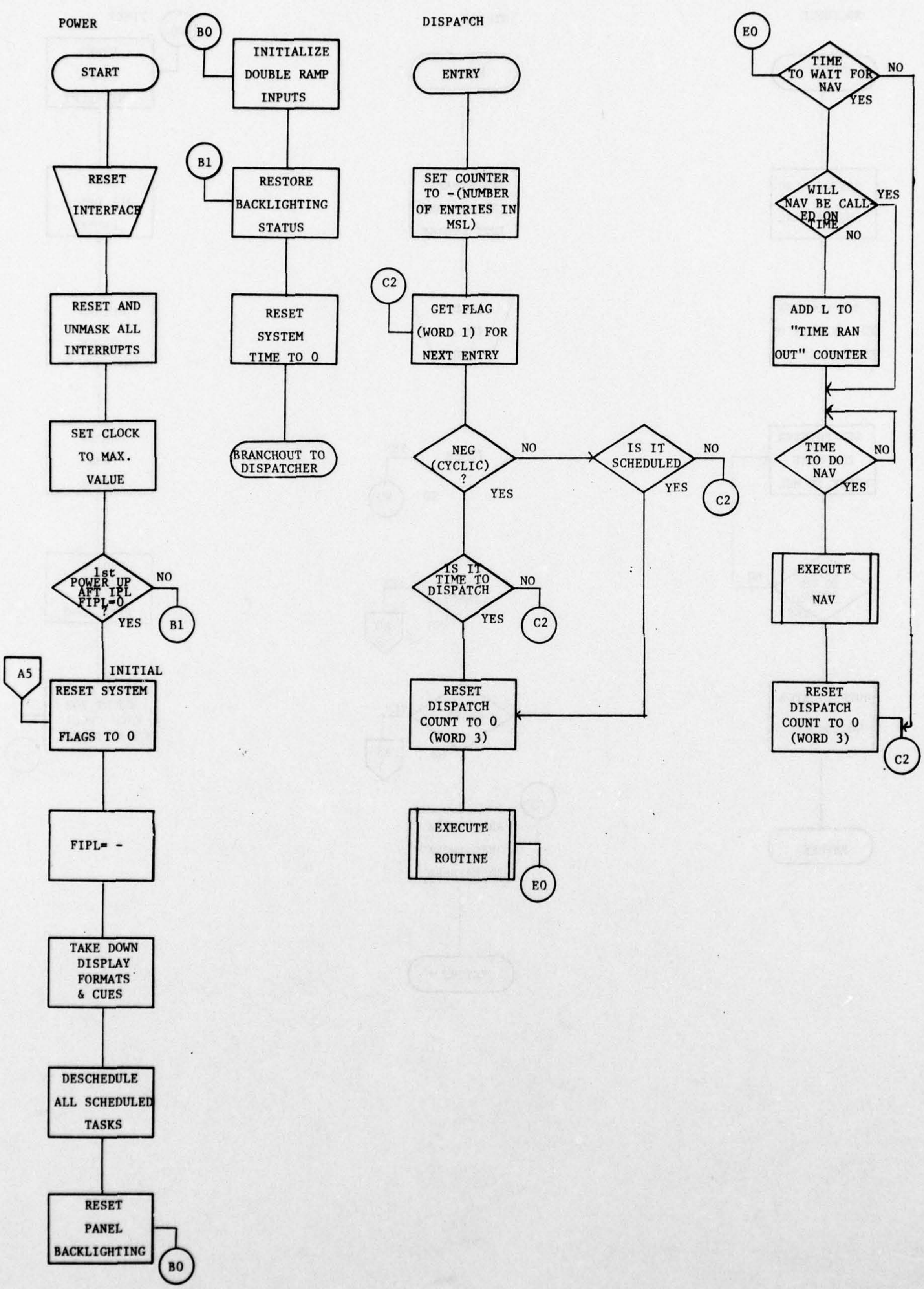


Figure 2. Program Flowcharts

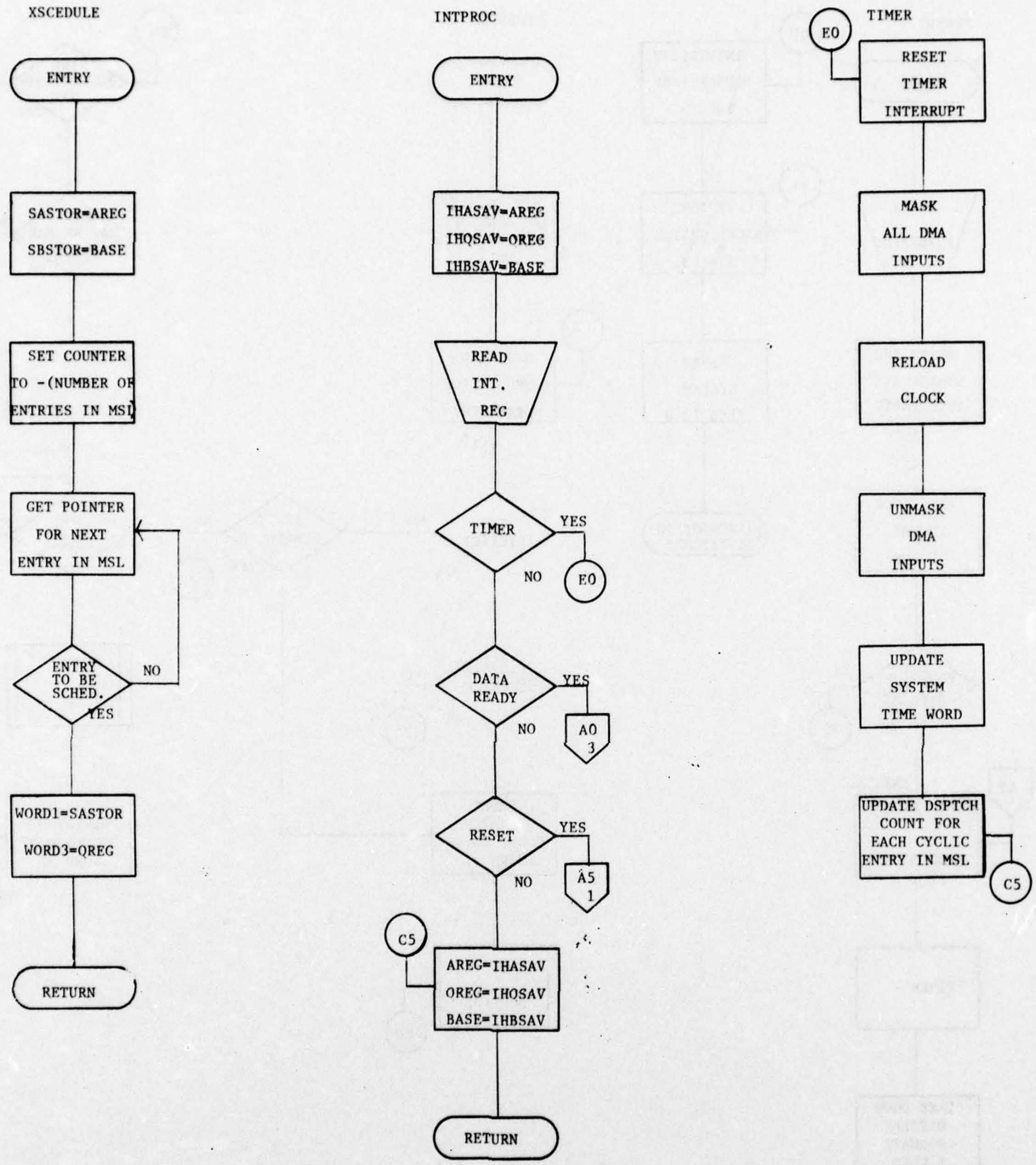
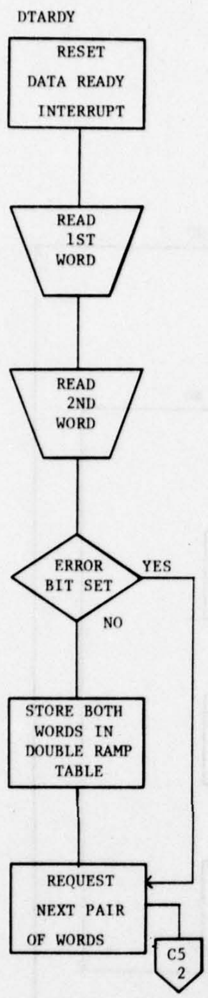


Figure 2. Program Flowcharts (Continued)



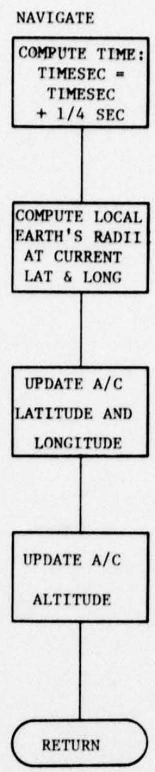
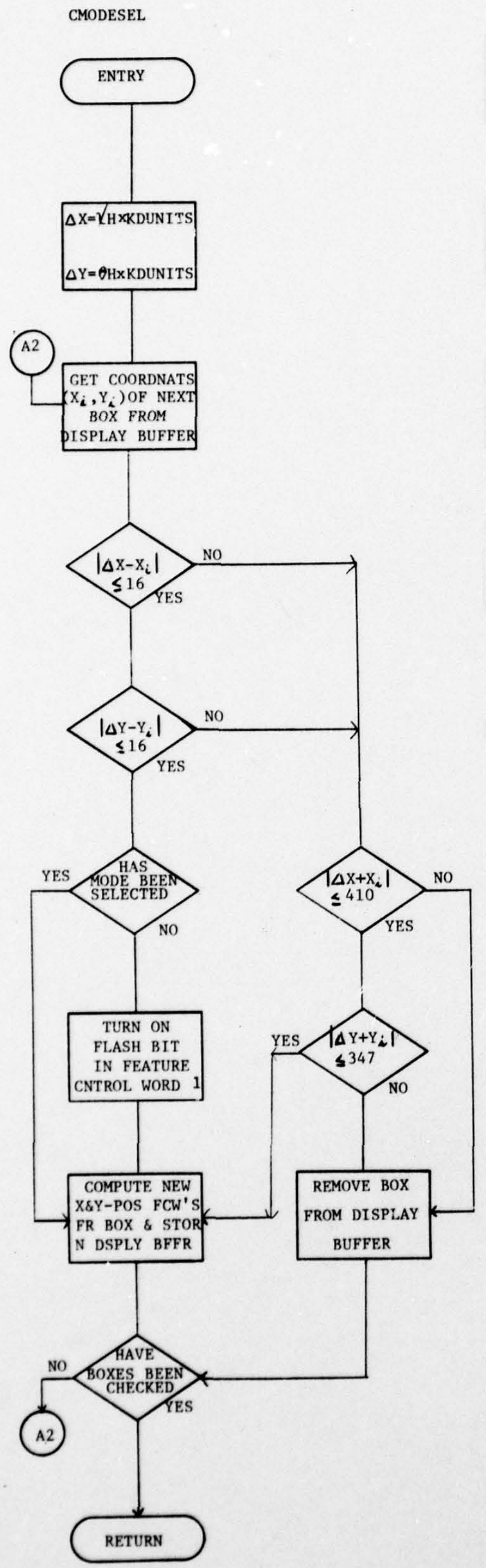


Figure 2. Program Flowcharts (Continued)



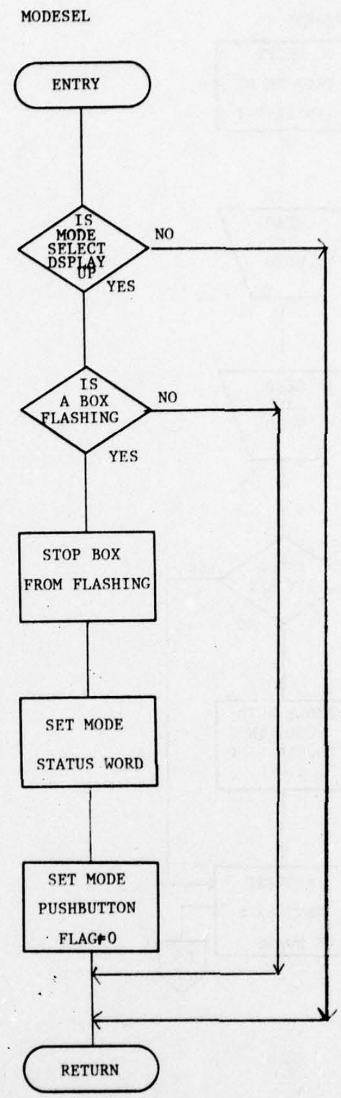


Figure 2. Program Flowcharts (Continued)

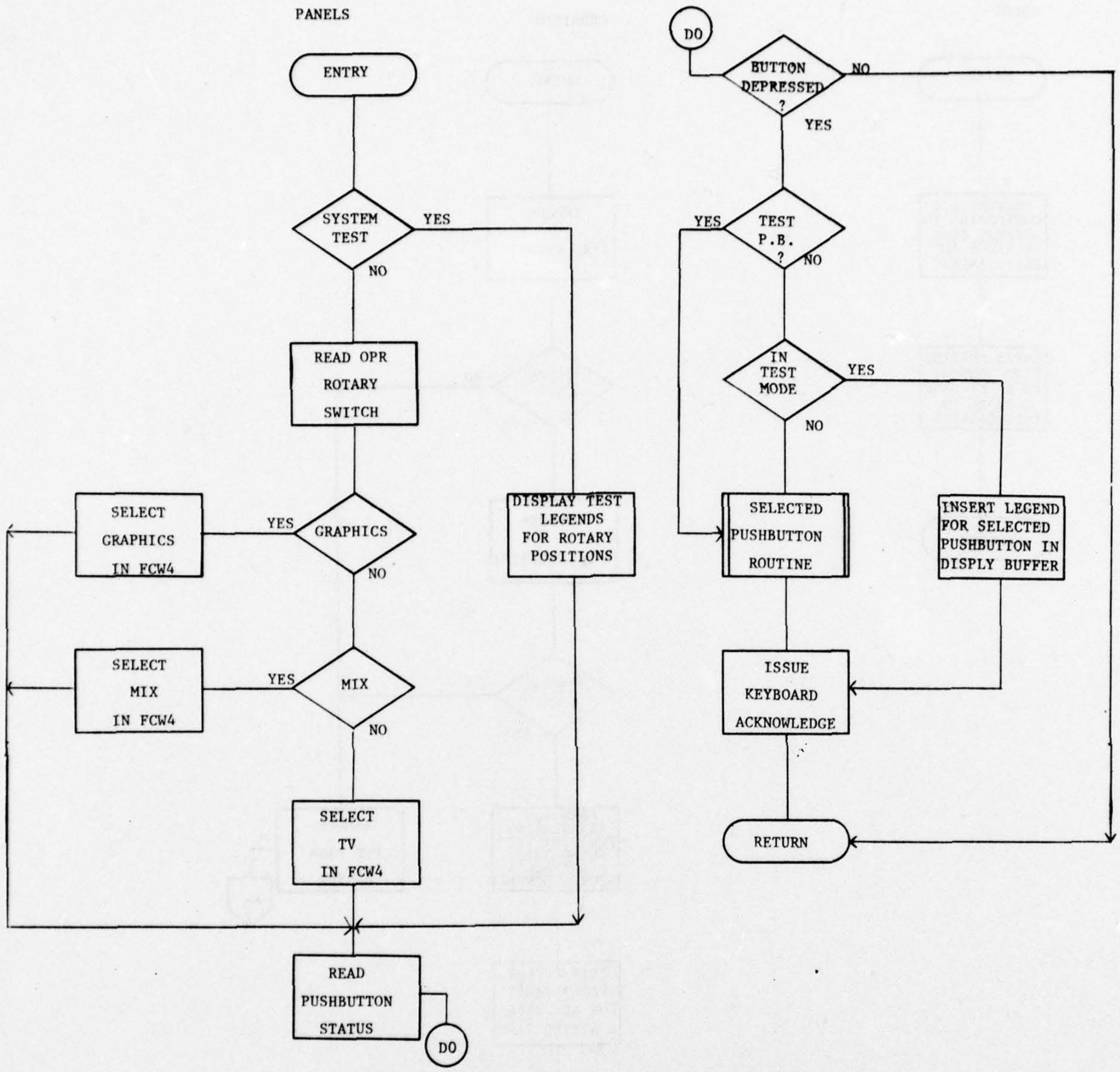


Figure 2. Program Flowcharts (Continued)

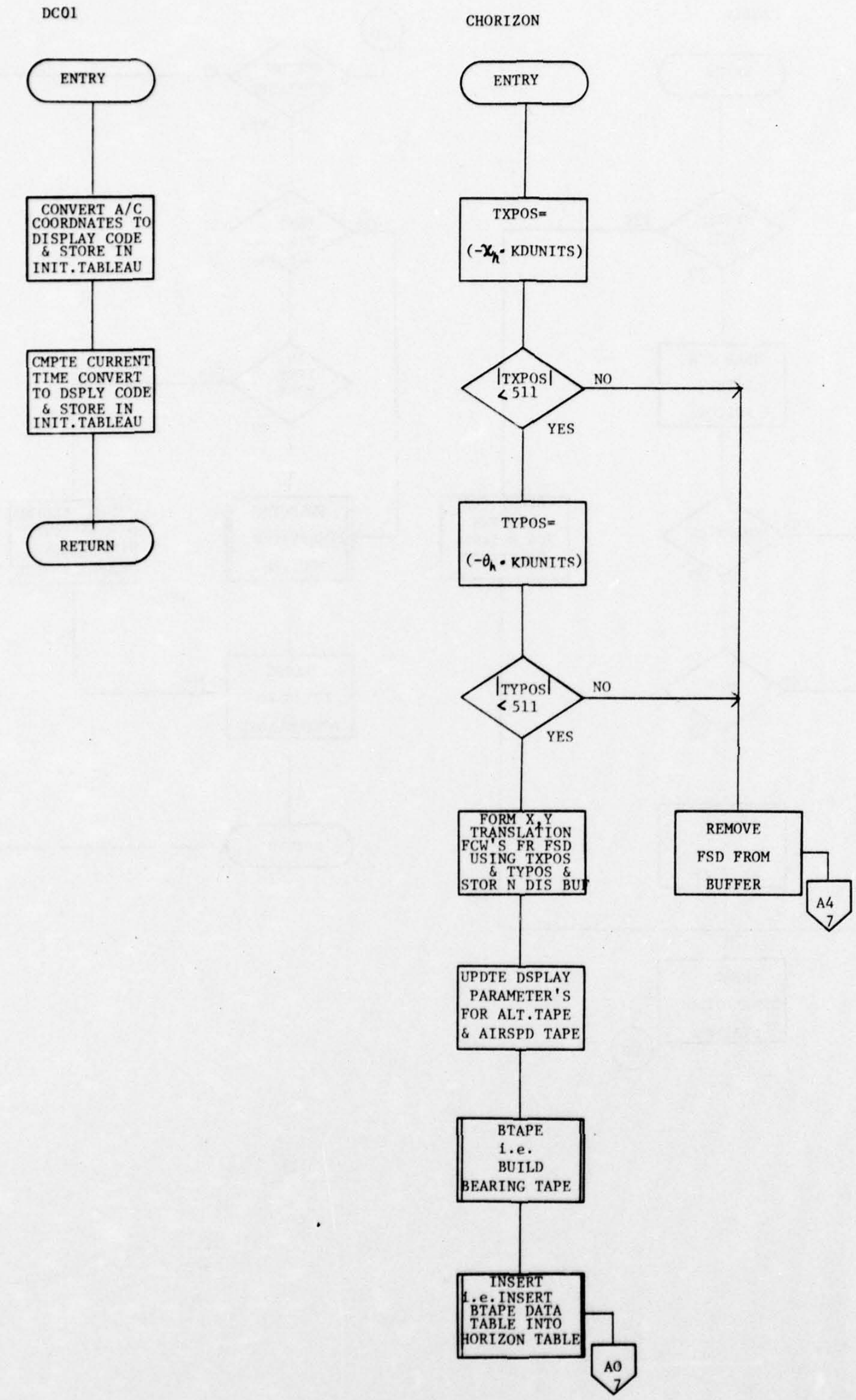


Figure 2. Program Flowcharts (Continued)

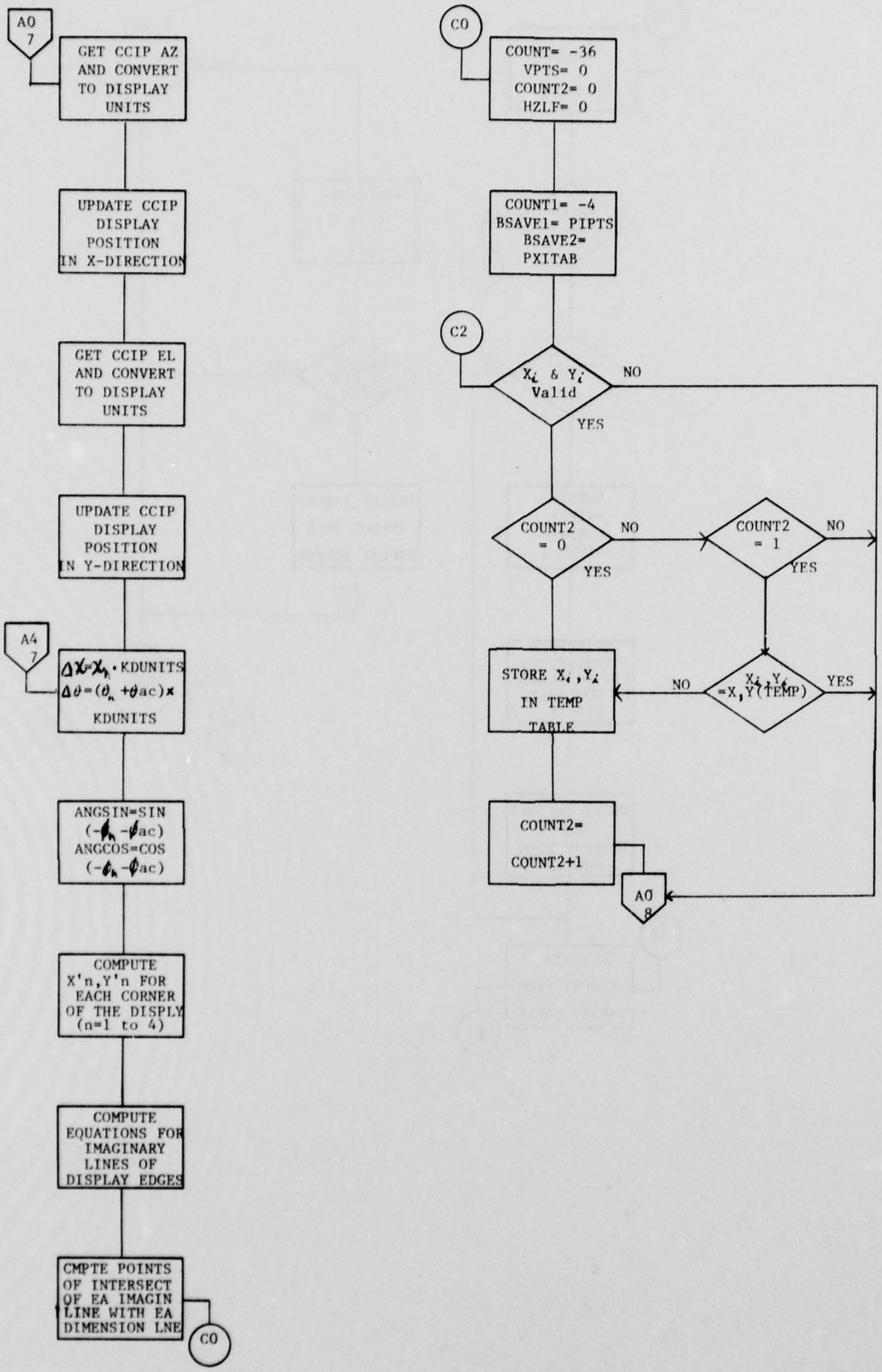


Figure 2. Program Flowcharts (Continued)

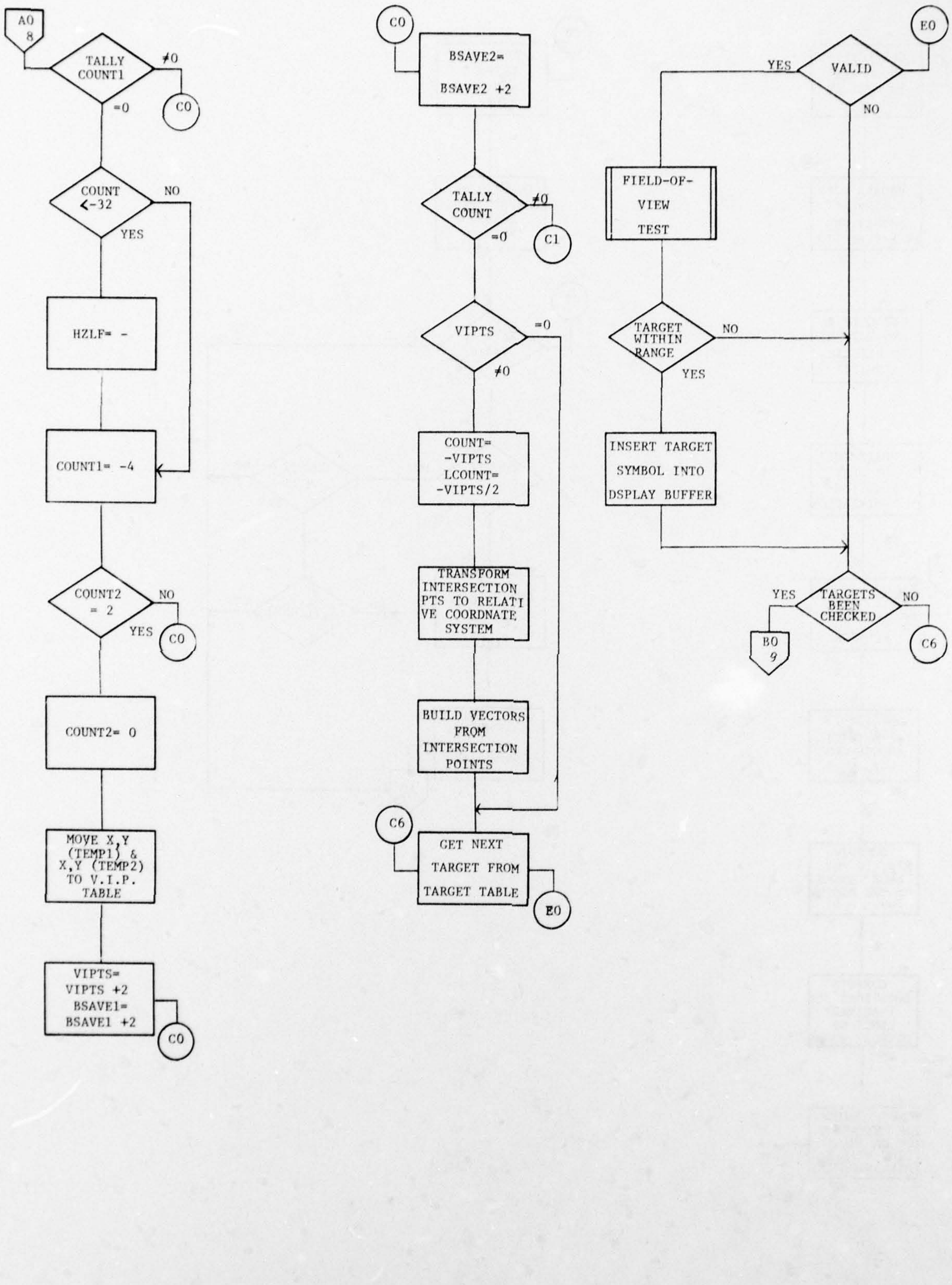


Figure 2. Program Flowcharts (Continued)

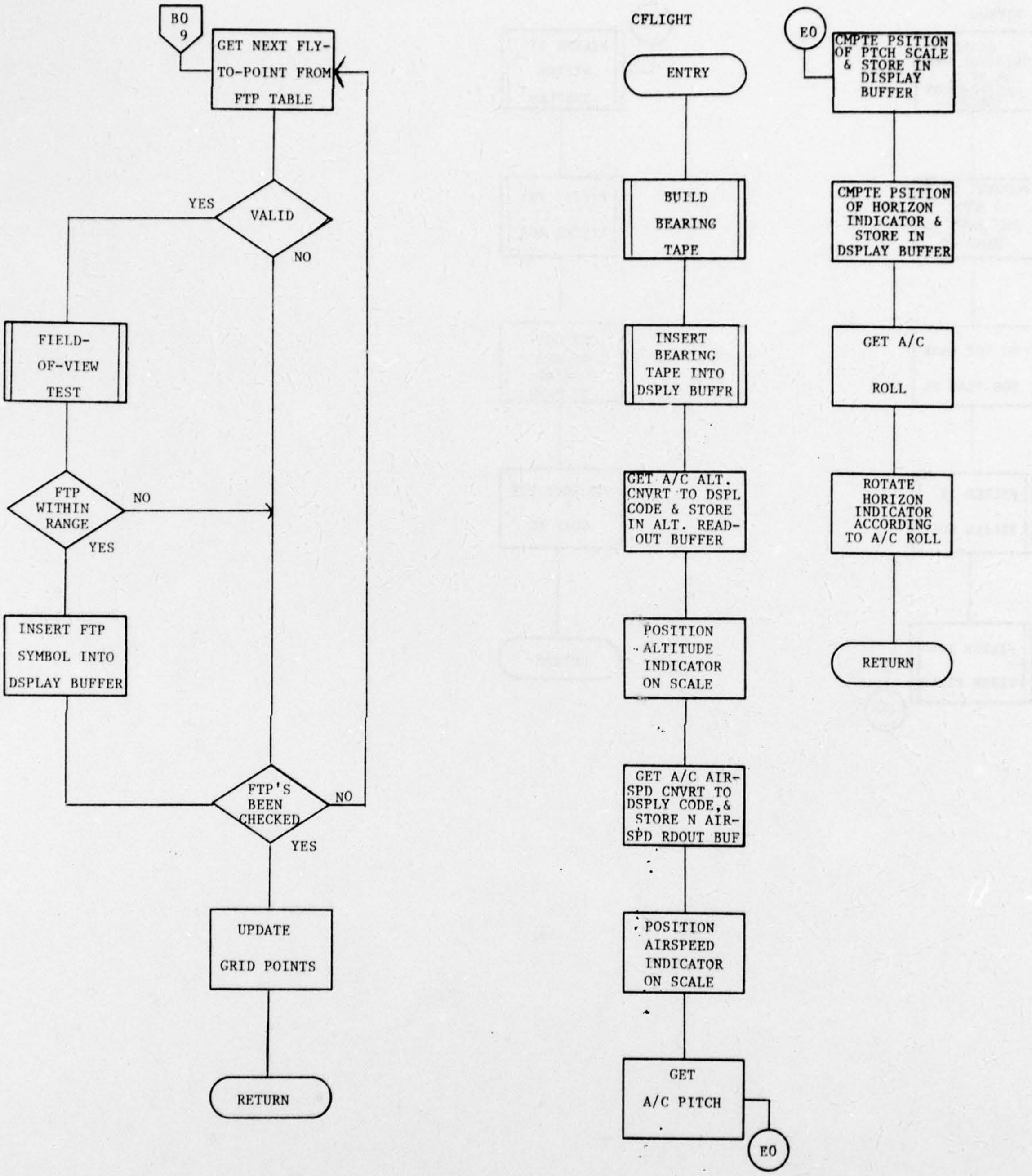


Figure 2. Program Flowcharts (Continued)

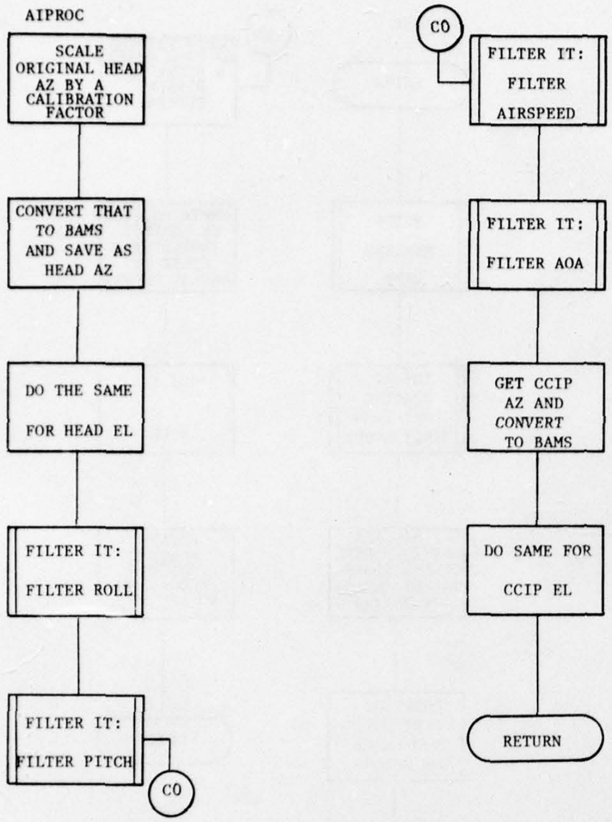


Figure 2. Program Flowcharts (Continued)

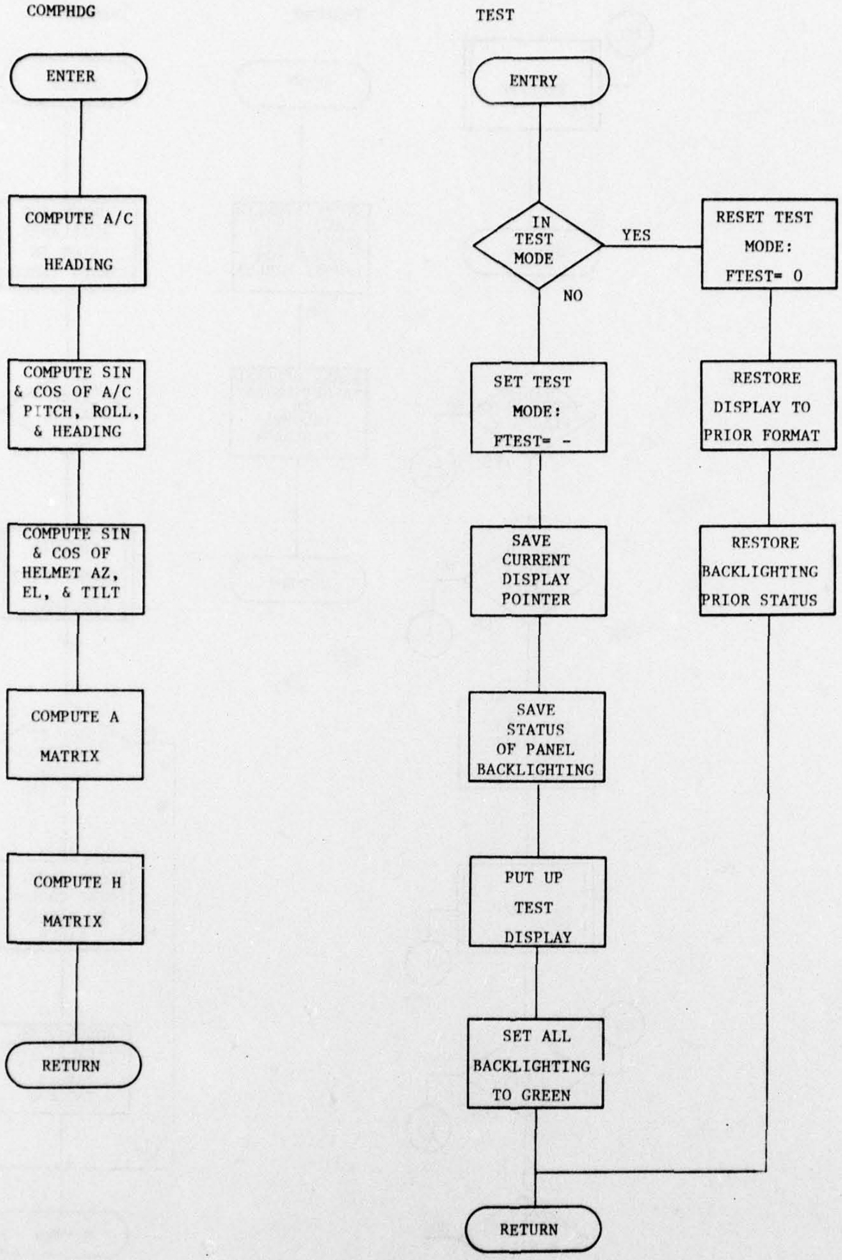


Figure 2. Program Flowcharts (Continued)

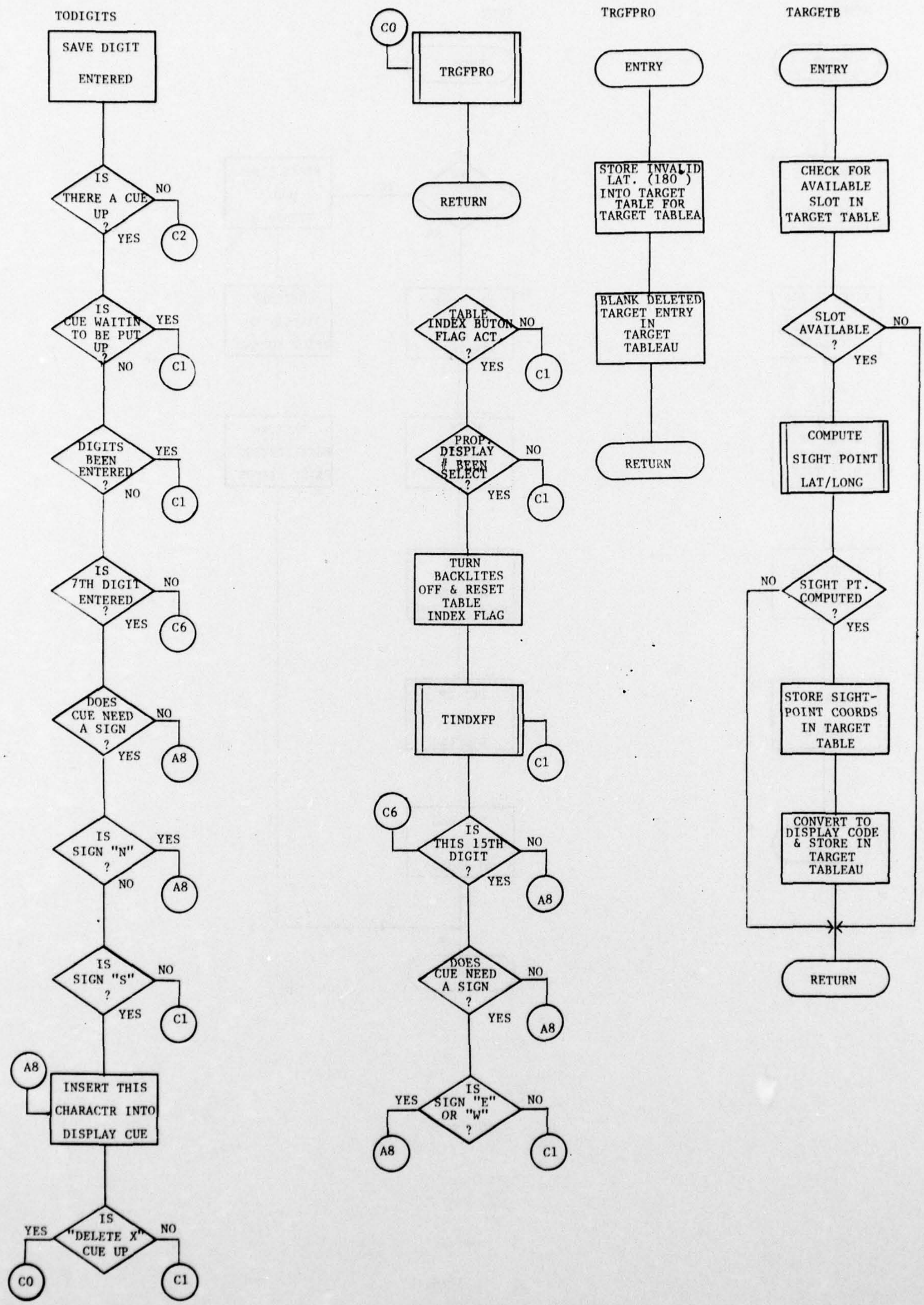


Figure 2. Program Flowcharts (Continued)

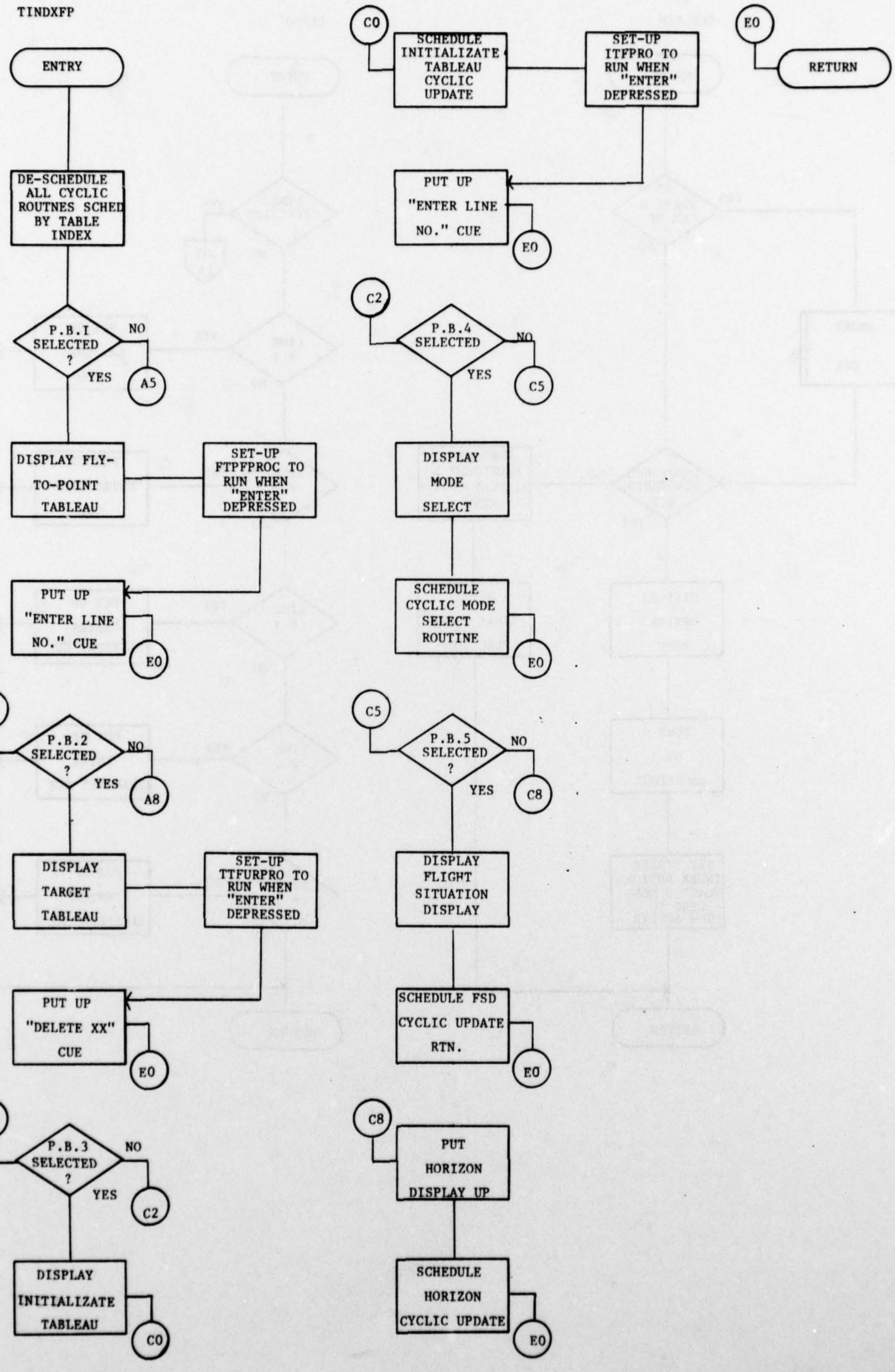


Figure 2. Program Flowcharts (Continued)

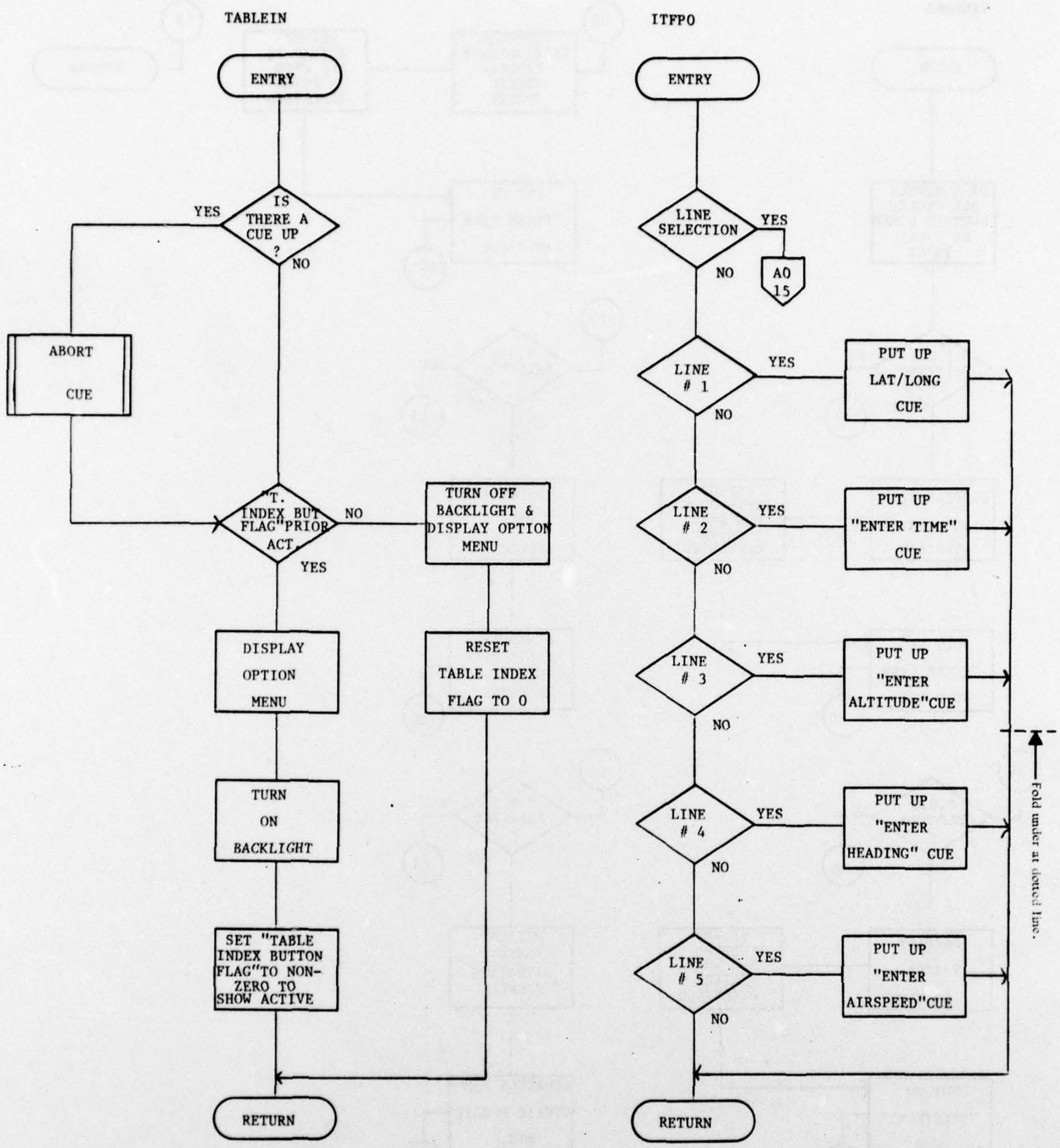
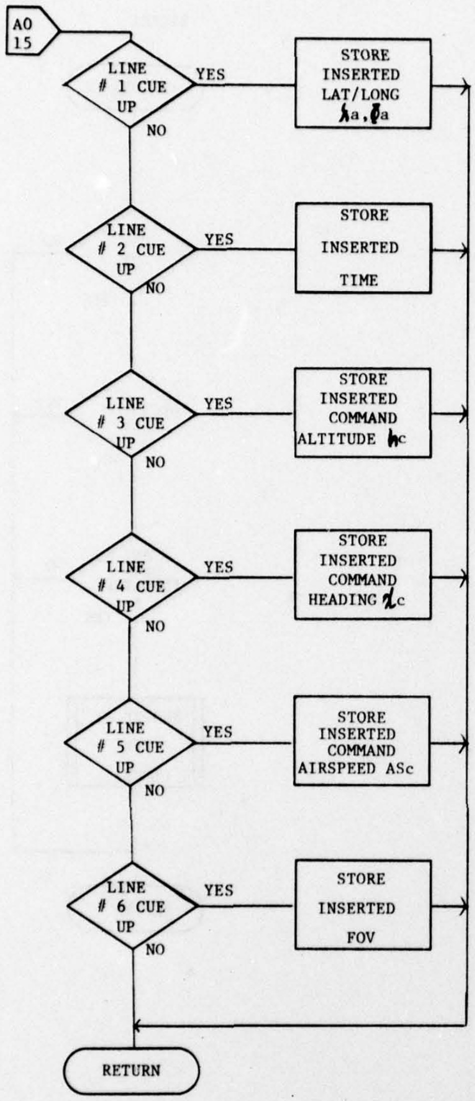


Figure 2. Program Flowcharts (Continued)



FTPFPROC

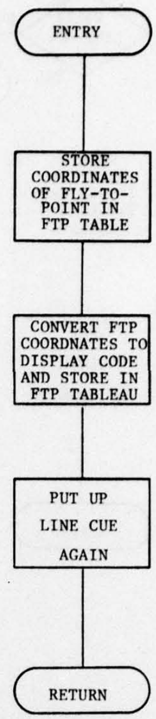


Figure 2. Program Flowcharts (Continued)

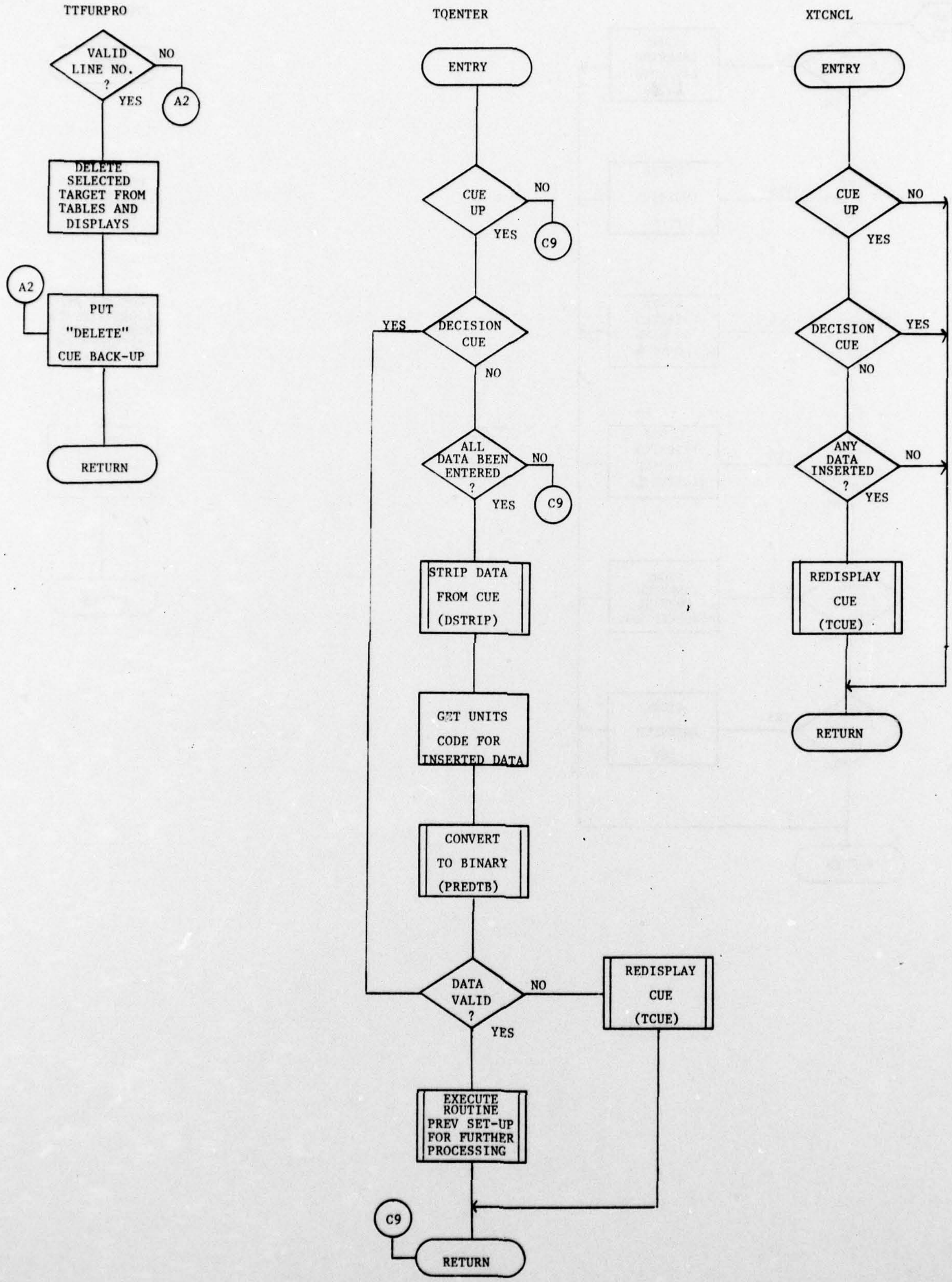


Figure 2. Program Flowcharts (Continued)

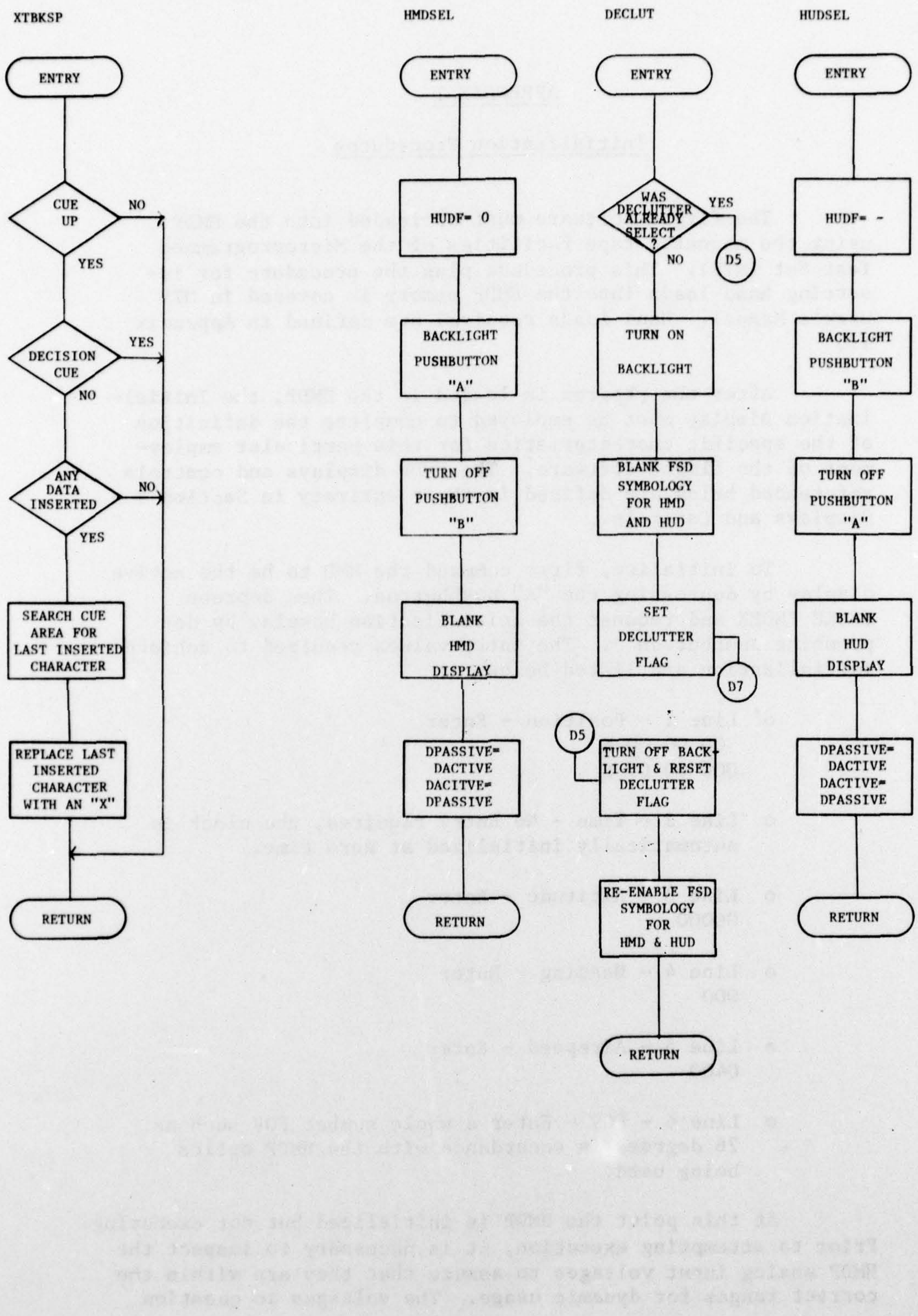


Figure 2. Program Flowcharts (Continued)

APPENDIX I

Initialization Procedures

The flight software must be loaded into the HMDP using the magnetic tape facilities of the Microprogrammed Test Set (MTS). This procedure plus the procedure for inserting hand loads into the HMDP memory is covered in MTS User's Manual. Hand loads required are defined in Appendix II.

After the program is loaded in the HMDP, the Initialization Display must be employed to complete the definition of the specific characteristics for this particular employment of the flight software. The HMDP displays and controls referenced below are defined in their entirety in Section V - Displays and Controls.

To initialize, first command the HMD to be the active display by depressing the "A" pushbutton. Then depress TABLE INDEX and request the Initialization Display by depressing pushbutton 3. The entry values required to achieve initialization are listed below:

- Line 1 - Position - Enter
  00 00 00 N
  000 00 00 E

- Line 2 - Time - No Entry required, the clock is automatically initialized at zero time.

- Line 3 - Altitude - Enter
  00000

- Line 4 - Heading - Enter
  000

- Line 5 - Airspeed - Enter
  0400

- Line 6 - FOV - Enter a whole number FOV such as 26 degrees in accordance with the HMDP optics being used.

At this point the HMDP is initialized but not executing. Prior to attempting execution, it is necessary to inspect the HMDP analog input voltages to assure that they are within the correct ranges for dynamic usage. The voltages in question

are those that are used to transmit biphase values to the HMDP, that is:

Position - 2 biphase inputs
Heading - 1 biphase input
Altitude - 1 biphase input

These biphase values are used to transmit the sine and cosine components of a rotating vector and must be within the voltage limits specified for each of them in Section IV - Input-Output Formats. These limits must be respected at all times. In addition, the limits are applicable regardless of whether the source of the voltage is from the S/370 or the potentiometer panel.

If using the potentiometer panel, the limits can be checked easily by visual inspection of the polarity switches and current dial indication for each potentiometer. It is recommended that to stay safely within the limits, voltage values read from the dials never exceed one-half the limit value of the component vector. In addition, it is recommended that zero-length components on both axes should be avoided because additive noise can cause rapid false rotations of the represented vector position. From Section IV, it should be noted that zero-length components are defined by voltages near zero for heading and at voltages near positive 5 volts for position and altitude.

If using voltages received from TFD, the limits need not be checked unless an electrical failure in the transmission link is suspected. This is because TFD provides proper limitation at all times, whether flying or frozen. However, a very important procedure must be followed prior to executing the HMDP software when following inputs provided by TFD. This procedure involves assuring that the current TFD values for heading and altitude are no more than one-half of a modulo circle above the HMDP initialization values. That is, TFD must be at a heading between 0° and 10°, and altitude between 0 to 1,000 feet. This is easily achieved by flying TFD to a heading and altitude within these limits and then freezing TFD. It is not necessary to achieve any particular geographic coordinate with TFD prior to the freeze even though position is transmitted on a modulo basis. The flight software has exclusive control of the start point at 00 00 00 N and 000 00 00 E.

After TFD is frozen at the recommended heading and altitude, the execution of the flight software can be commanded. The command is given by requesting the Horizon Display and then depressing the ENTER key. It should be noted that the Horizon Display will indicate "NO-GO" until the

ENTER key is depressed, and then "NO-GO" disappears indicating that the flight software is cycling.

Before unfreezing the aircraft, it is recommended that the Flight Situation Display be inspected to assure that the heading and altitude values match those of the TFD instrument panel. If they do, the transmission link for heading and altitude is ready for dynamic usage and the TFD aircraft may be allowed to fly.

If the altitude or heading link becomes uncoordinated due to flying TFD during an HMDP halt, the condition can be corrected by holding the HMDP in a halt while flying the TFD to achieve a heading and altitude that matches that of the HMDP displays. Then, the TFD should be frozen, the HMDP commanded to continue, and finally the TFD should be unfrozen. The initialization display should not be used for restarts because initialization causes establishment of basic conditions in the program and these will be valid only at the first transition from NO-GO to GO.

Listed below is a capsulized step-by-step procedure for achieving initialization and coordination when using the inputs provided by TFD:

1. Load Program
2. Insert Handloads
3. Use Initialization Display
4. Fly TFD to Heading & Altitude
5. Freeze TFD
6. Call Horizon Display and ENTER
7. Verify Coordinated Heading and Altitude
8. Unfreeze TFD

If using the potentiometers for inputs to HMDP, the procedure is:

1. Load Program
2. Insert Handloads
3. Use Initialization Display
4. Check Dials for Limit Conditions
5. Call Horizon Display and ENTER

APPENDIX II

Handloads

The handloads that follow are modifications that have been made directly to the object code on the SP-1 object magtape. These changes would need to be made to the source deck to obtain an updated corrected source deck.

Loc	Contents		Source Statement	Comments
03D4	EE00		NOP	Take bias out of A/D value.
0645	4F48		BN@ GPC	Permits program to compute GP's
2855	308C	DS	HEXF 308C	for 2 mi. spacing.
0C34	A76E		AD PHIA	Corrects sightpoint computations.
12BF	1A80		Display Br to 1A80	Branch to LOS symbol.
1A80	3005		Feature control word 2	Now put up LOS symbol
1A81	501E		MAJOR 30	as part of display program.
1A82	35EF		Feature control word	
1A83	60B0		XSIZE	
1A84	68B0		YSIZE	
1A85	8000		XPOS 0	
1A86	9000		YPOS 0	
1A87	C980			
1A88	12C0		Display Br to 12C0	Branch back to normal execution.
29F3	1A80	PHBTE	PTR 1A80	
2822	9428		LA 40,1	Use channel 3 of AC for CCIP EL.
2875	4E12		BN HGPTS2	Allow GP field-of-view test to fail or pass.
0280	3000		PTR 3000	
0281	2881		PTR 2881	
2880	4180		B@ 280	Blank GP display when FOV test fails.
3000	5124		BAL XYPOS	
3001	1EFF		MBI -1	
3002	9600		LAI 0	
3003	9C00		STA 0,1	
3004	4181		B@ 281	
29E8	EF07		0 X8000	Correct CCIP AZ and EL position.
29EF	EF09		0 X9000	

The next 2 locations control the tracking ability of the head azimuth and elevation for better stabilization of the head with real terrain. They should be initially loaded with the following values then manually increased or decreased in value for best head tracking performance. These initial values provide good head tracking at 26° FOV.

Loc	Contents	Source Statement
016A	071C	AZFAC HEXF 071C
016B	0980	ELFAC HEXF 0980

☆U.S.Government Printing Office: 1978 — 657-002/293